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Evaluation of Mechanical Properties of Polyester & Fly Ash Fiber Reinforced Polymer Composites

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Abstract: In this research, Fibre Reinforced Polymer artificial composites are fabricated as a high-strength and lightweight. The artificial fibre of e-glass fibre and fly ash powder are used as a particulate reinforcement for our application. The mechanical strength of these fibre composites is improved by analysis and testing with different compositions of resin, catalyst and accelerator presented in this fibre. The composite samples were fabricated at varying particulate weight content (%) and at room temperature. Finally, by this project we can analyse the tensile strength and impact strength of e-glass fiber and fly ash are improved. These composites can help us to achieve a better combination of properties. The characteristics of these composites are durable, low cost, low weight, high specific strength, non-abrasive, equitably good mechanical properties, Eco friendly and biodegradable.

Keywords: Epoxy, e-glass fibre, fly ash, Mechanical Properties.

I. INTRODUCTION

A. Background

With the recent technological advances in engineering, material science has assumed a position of utmost importance. The interest in advanced materials is increasing rapidly, both in terms of their research and application. It is a truism that technological development depends on advances in the field of materials. One does not have to be an expert to realize that the most advanced turbine or aircraft design is of no use if the adequate materials to bear the service loads and conditions are not available. Whatever the field may be, the final limitation on advancement depends on materials. Composite materials in this regard represent nothing but a giant step in the ever constant endeavor of the optimization in materials.

The mechanical shortcomings of homogenous materials and the need for composites were realized in the early 1950s, with the advent of the space age. Almost all homogenous materials have their inherent shortcomings in mechanical respect. When they are stiff and sufficiently hard, they are most brittle and hardly processable. They are ductile and well processable; they are not stiff and hard enough. By the combination of materials, it proved possible to attain a situation in which the “whole is more than the sum of its parts”. Composites were a need in the evolution of engineering materials. The simplest combination is that of only two materials, one acting as reinforcement and the other as the matrix.

II. LITERATURE REVIEW

This section focuses on the research work that has already been carried out for testing the mechanical properties of the glass Fiber Reinforced Hybrid composites. Literature review of such work needs to be done in order to understand the background information available, the work already done and also to show the relevance of the current project. This chapter presents a general idea of the factors which affect the mechanical properties of hybrid fibre reinforced polymer composites. In polymer composites, the matrix is the major load bearing component. In order to increase this load bearing capability, the reinforcements are introduced in the matrix. Currently, natural fibers and artificial fibers like glass, jute etc., are being widely used in polymer-based composites because of their high strength and stiffness properties.

According to R.D.HEMANTH, M.SENTHILKUMAR, AJITHGOPINATH & L. NATRAYAN Composite manufacturing is the novel branch of science, which finds its immense applications in various industries such as sporting, automotive, aerospace and marine industries. The superior properties of composites such as stiffness, better mechanical properties, low density and light weight make it a candidate in engineering applications. The need for seeking alternate materials with increased performance in the field of composites revived this research, to prepare fiber reinforced composites.

According to A. MANIKANDAN, R. RAJKUMAR et al The objective of this work is to investigate the mechanical properties of Glass fiber reinforced Epoxy composites with different weight proportions. Using injection molding, five composites were prepared by varying the weights. The necessary mechanical tests were conducted as per ASTM standards. Fiber Reinforced Polymer (FRP) composite materials are currently considered as universal engineering materials and they are utilized in a spacious range of

applications, because of their elevated specific strength and high specific stiffness. They play vital roles in the automotive industry, aviation and aerospace and they are also used in the construction of submarines, ships, chemical and nuclear facilities, etc.

According to Dr. P. ANAND, M, KARTHIK, M. SUNDAR RAJ., Natural fiber is a manufactured assembly of long or short bundles of fiber to produce a mat layer of one or more layers of flat sheet. Natural fiber like abaca, cotton, jute, flax, hemp and coir are deployed for different industrial applications. Recently, there has been a rapid growth in research and innovation in natural fiber composites. The characteristics of natural fiber composites are durable, low cost, low weight, high specific strength, non-abrasive, equitably good mechanical properties, eco-friendly and bio degradable. These materials possess promising potential for a wide range of industries enfold aerospace and automobile industry.

According to P. RAVI SHARMA, SHARAD SRIVASTAVA et al Hybrid composites are manufactured by combining two or more fibers in a single matrix. Hybrid composites can be made from artificial fibers, natural fibers and with a combination of both artificial and natural fibers. Hybrid composites can help us to achieve a better combination of properties than fiber reinforced composites. The constituent fibers in a hybrid composite can be altered in a number of ways leading to variation in its properties.

According to ASIM SHEHZAD, NAZIA et al Natural fiber composites are often poorer in properties, mostly mechanical, compared to synthetic fiber composites. A possible solution to this issue is the use of natural fiber/synthetic fiber combination in polymer hybrid composites. Although the biodegradability of the composites is compromised by synthetic fibers, this is compensated by the improvement in their mechanical and physical properties. Hybrid composites use more than one kind of fibers in the same matrix and the idea is to get the synergistic effect of the properties of both fibers on the overall properties of composites. There has been a significant increase in research on natural fiber/synthetic fiber hybrid composites in recent years. Natural fibers are mostly hybridized with glass fibers because of their comparable properties and low cost.

III. METHODOLOGY

Study of different materials like glass fibers, artificial fibers, different resins, different techniques, different mechanical tests etc. E-glass fiber, Fly-ash, Unsaturated Polyester resin, Accelerator and Catalyst materials are selected. Moulds are prepared as per ASTM standards by using different methods and materials Fiber reinforced composites are prepared by different weight proportions. Different mechanical tests are performed on prepared fiber reinforced composites. Graphs are drawn and results are compared.

A. Fabrication Of Thermoset Composites

Thermoset composites are fabricated either using “wet-forming” processes, or processes which used premixes or prepregs. In wet-forming processes, resin in fluid state is used, while forming the final product. The resin gets cured in the product while the resin is “wet”. This curing may be aided by application of external heat and pressure. Typical wet-forming processes include: – Hand layup, Bag moulding, Filament winding, RTM (resin transfer molding) Pultrusion.

B. Hand Layup Process

Hand Layup: This method is also known as contact-layup . It is the oldest, most commonly used, and the simplest method for fabrication of thermoset composites. This method is appropriate for low volume production, and when capital costs need to be minimized. This method is frequently used to fabricate boats, ducts, pools, furniture, shells and sheets (corrugated (corrugated or flat). This method essentially requires a flat surface (for making sheets), or a mould and cavity for providing shape to the final product. The moulding tool may be made from metals, plastics, wood, or some other appropriate material.

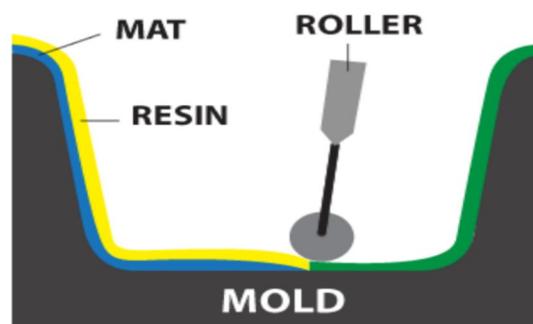


Fig 1: HAND LAYUP PROCESS

While fabricating composite products with long fibers, reinforcing fibers (in form of mats or fabric) are placed layer by layer over the surface, to ensure appropriate stacking sequence, as well as requisite thickness of the product. Once a particular layer of fiber is placed, it is coated with a layer of resin either through a spray gun, or through a brush. Care is taken to ensure that resin is devoid of air bubbles, as it is applied to reinforcing fibers. For this, serrated rollers may be used, which help remove air bubbles, as well as ensure increased wetting of fibers. This manual method of layup may also be used for short fiber composites.

IV. EXPERIMENTATION

Materials used are E-glass fiber, Fly-ash, Unsaturated Polyester resin, Accelerator (Cobalt Octate), Catalyst (MEKP), E-GLASS: High strength glass made with aluminosilicates. Used where high strength, high stiffness, extreme temperature resistance, corrosive resistance is needed. E-Glass has a typical nominal composition of SiO₂ (65wt%), Al₂O₃ (25wt%), CaO(10wt%). E-glass does not actually melt, but softens instead, the softening point being the temperature at which a 0.55–0.77 mm diameter fiber 235 mm long, elongates under its own weight at 1 mm/min when suspended vertically and heated at the rate of 5 °C per minute. Having a density of 2.55 mg/m³.

A. Fly-Ash

It is a long, soft, shiny fiber that can be spun into coarse. It is one of the cheapest particulate and produced from the burning of younger lignite or sub-bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, fly ash hardens and gets stronger over time. Fly ash generally contains more than 20% lime (CaO). Fly ash does not require an activator. Alkali and sulfate (SO contents are generally higher in fly ashes).

B. Unsaturated Polyester Resin

Polyester resin is a type of resin that possesses tough mechanical properties, good chemical resistance, and high adhesive strength, which makes it highly useful for various applications. Polyester resin also finds uses in caulking and casting compounds, sealants, varnishes and paints, and other industrial applications. Polyester resin is superior to other types of resins because it has low shrink during cure, and excellent moisture and chemical resistance. It is impact resistant, it has good electrical and insulating properties, and a long shelf life. The various combinations of epoxy resins and reinforcements gives a wider range of properties obtainable in molded parts.

C. Accelerator And Catalyst

Cobalt octate joints are water proof, heat proof, stress proof, and resistant to most chemicals. Non-corrosive and non-toxic. Unsaturated polyester resins have the following outstanding properties: Excellent adhesion to many different materials Great strength, toughness and resilience Excellent resistance to chemical attack and to moisture Outstanding electrical insulating properties Absence of volatiles on curing Negligible shrinkage Other epoxy resins for bonding, casting, tooling, pattern making, surface coating, lamination and concrete repairs are available.

D. Experimentation Process

Mould preparation, Preparation of artificial fiber samples, Preparation of fly ash particulates, Preparation of artificial and fly ash composites, Curing, Finishing, Resulting.

E. Mold Preparation

The wooden moulds are prepared as per requirements. And grease or any oil is applied to the mould for smooth removal of the specimen.



Fig 2: Preparation of Mould

F. Fabrication Of Artificial Fiber Composites

Here we are using hand layup technique for preparing samples. A mixture of Polyester resin and hardener is mixed in equal ratio for example if we take 100 ml of resin, we have to take 10 ml of accelerator i.e., 10:1 ratio of resin and catalyst mixture is taken for each layer of specimen preparation. Then the prepared dough was transferred to the prepared moulds with care that the mould cavity should thoroughly filled. Levelling was done for uniformity of the layer.

While the process is going on the glass fiber is cut ten as per the mould dimensions and placed on that base layer and then a layer of resin and accelerator mixture is gently applied with the help of a roller. One layer after another is gently applied and the process goes on till, we obtain required thickness of the specimen as per standard dimensions with required ratio of glass fiber and resin mixture.

G. Preparation Of Fly-Ash Particulates

Fly ash is produced by coal fired. Typically, coal is pulverized and blown with air where it immediately ignites, generating heat and producing a molten mineral residue. the molten mineral residue to harden and form ash. Coarse ash particles, referred to as bottom ash or slag, fall to the bottom of the combustion chamber, while the lighter fine ash particles, termed fly ash, remain suspended in the flue gas. Prior to exhausting the flue gas, fly ash is removed by particulate emission control devices, such as electrostatic precipitators or filter fabric baghouses.

H. Preparation Of Artificial And Fly Ash Composites

Here we are using hand layup technique for preparing samples. A mixture of polyester resin and accelerator is mixed in different ratio for example if we take 100 ml of resin we have to take 10 ml of catalyst i.e., 10:1 ratio of resin and accelerator mixture is taken for each layer of specimen preparation. Then the prepared dough was transferred to the prepared moulds with care that the mould cavity should thoroughly filled.

Levelling was done for uniformity of the layer. While the process is going on first one layer of e-glass fiber is placed and then a layer of resin and catalyst, accelerator mixture is gently applied with the help of a roller. Next a layer of glass fiber is placed on the mould and a mixture of resin and hardener is applying on these layers. One layer after another is gently applied and the process goes on till, we obtain required thickness of the specimen as per standard dimensions with required ratio of jute fiber, glass fiber and resin, accelerator and catalyst mixture.

I. Curing

After the specimen is prepared then it must be cured for few hours at room temperature or at a place where it cures quickly.

J. Demolding

The cured work piece is removed from mould and cut into the standard dimensions for testing.

K. Cutting Of Laminates Into Samples Of Desired Dimensions

A WIRE HACKSAW blade was used to cut each laminate into smaller pieces, for various experiments. TENSILE TEST- Sample was cut into dog bone shape as per ASTM D-638(TENSILE), IMPACT TEST- Sample was cut into flat shape with notch at centre as per ASTM D-256(IMPACT).

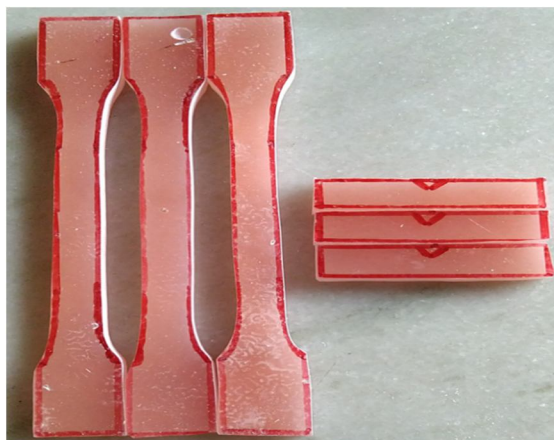


Fig 3: Resin Specimens for Tensile and Impact tests

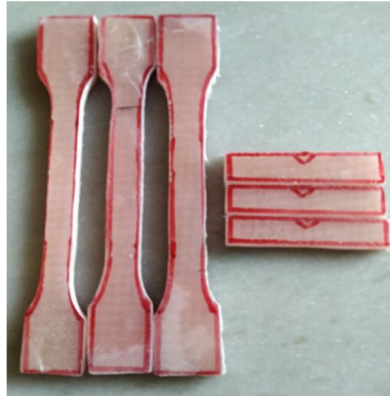


Fig 4: Resin and E-glass fiber Specimens for Tensile and Impact tests

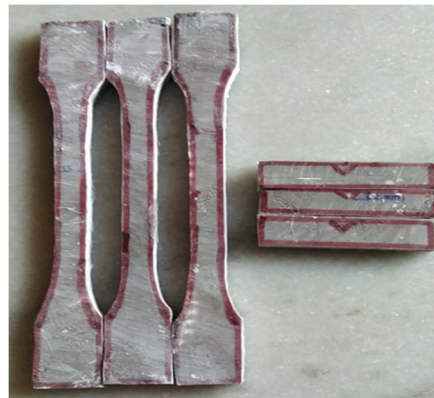


Fig 5: Resin, E-glass fiber and Fly-ash Specimens for Tensile and Impact tests

L. Tensile Test

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. The commonly used specimen for tensile test is the dog bone type. During the test a uni-axial load is applied through both the ends of the specimen. The dimension of specimen is per ASTM E8 (TENSILE). Typical points of interest when testing a material include, ultimate tensile strength (UTS) or peak stress; offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation ; and the rupture (R) or fracture point where the specimen separates into pieces. The tensile test is performed in the universal testing machine (UTM) and results are analysed to calculate the tensile strength of composite samples .Tensile strength is calculated by dividing the load at break by the original minimum cross sectional area. The result is expressed in mega Pascal's (MPa).

$$\text{Tensile strength} = \frac{\text{load at break}}{((\text{original width}) * (\text{original thickness}))}$$



Fig 6: Specimens after Tensile Test

M. Impact Test

Impact strength, is the capability of the material to withstand a suddenly applied load and is expressed in terms of energy. Often measured with the Izod impact strength test or Charpy impact test. Low velocity instrumented impact tests are carried out on composite specimens. The tests are done as per ASTM D 256 using an impact tester. The charpy/Izod impact testing machine ascertains the notch impact strength of the material by shattering the V-notched specimen with a pendulum hammer, measuring the spent energy, and relating it to the cross section of the specimen. The standard specimen for ASTM D 256 is 64 x 12.7 x 3.2 mm and the depth under the notch is 10.2 mm



Fig 7: Specimens after Impact Test

This presents the mechanical characterization of the class of Polymer matrix composites developed for the present investigation. They are Unsaturated polyester resin mixture filled is 100 weight percentage. Glass fiber is 40% and polyester resin mixture filled is 60 weight percentage. Fly ash is 20% and polyester resin is 40% and E-glass fiber 40 weight percentage. The results of various characterization tests are reported here. They include evaluation of tensile strength, impact strength.

Table1: Resin properties

Properties	Specimen-1	Specimen-2	Specimen-3
Load at yield	0.62 KN	0.58 KN	0.58 KN
Elongation at yield	3.670 mm	3.525 mm	3.475 mm
Yield Stress	6.526 MPa	6.432 MPa	6.242 MPa
Load at peak	1.220 KN	1.110 KN	1.000 KN
Elongation at peak	9.160 mm	8.920 mm	8.880 mm
Tensile strength	12.842 MPa	10.842 MPa	9.992 MPa
Load at break	0.080 KN	0.076 KN	0.068 KN
Elongation at break	9.600 mm	9.542 mm	9.452 mm
Breaking strength	0.842 MPa	0.784 MPa	0.682 MPa

Table 2: Resin and fiber properties

Properties	Specimen-1	Specimen-2	Specimen-3
Load at yield	2.72 KN	2.69 KN	2.65 KN
Elongation at yield	5.570 mm	5.550 mm	5.545 mm
Yield Stress	28.632 MPa	28.432 MPa	27.942 MPa
Load at peak	5.360 KN	5.345 KN	5.220 KN
Elongation at peak	10.260 mm	10.120 mm	9.998 mm
Tensile strength	56.421 MPa	56.242 MPa	55.992 MPa
Load at break	0.460 KN	0.452 KN	0.445 KN
Elongation at break	11.690 mm	11.542 mm	11.252 mm
Breaking strength	4.842 MPa	4.652 MPa	4.602 MPa

Table 3: Resin, Fiber and fly ash properties

Properties	Specimen-1	Specimen-2	Specimen-3
Load at yield	5.36 KN	5.30 KN	5.28 KN
Elongation at yield	8.280 mm	8.115 mm	8.102 mm
Yield Stress	56.421 MPa	56.402MPa	55.995 MPa
Load at peak	6.770 KN	6.670 KN	6.645 KN
Elongation at peak	9.450 mm	9.420 mm	9.415 mm
Tensile strength	70.526 MPa	70.342 MPa	70.092 MPa
Load at break	0.020 KN	0.015 KN	0.012 KN
Elongation at break	9.820 mm	9.642 mm	9.452 mm
Breaking strength	0.211 MPa	0.202 MPa	0.199 MPa

N. Tensile Test Properties

The mean value of the tensile strength of the glass fibers with various specimens is 12.34 Mpa for 100% resin and 55.443 Mpa for 40% glass fiber and 60% resin and 70.093Mpa for 40% resin, 40% fiber and 20% flyash. It seems that increase in fiber percentage will increase in tensile strength. The test results shown in table seems that composite with fly ash and glass fiber has more tensile strength in artificial fiber composites.

The ability to resist breaking under tensile stress is one of the most important and widely measured properties of materials used in structural applications. The force per unit area (MPa or psi) required to break a material in such a manner is the ultimate tensile strength or tensile strength at break . The rate at which a sample is pulled apart in the test can range from 0.2 to 20 inches per minute and will influence the results. The analogous test to measure tensile properties in the ISO system is ISO 527. The values reported in the ASTM D638 and ISO 527 tests in general do not vary significantly and either test will provide good results early in the material selection process.

Table 4: observations for impact test

Composition	Impact strength(joules)
Resin (S1)	3
Resin (S2)	2
Resin (S3)	2
Resin + Fiber (S1)	10
Resin + Fiber (S2)	10
Resin + Fiber (S3)	9
Resin + Fiber + Fly-ash (S1)	23
Resin + Fiber + Fly-ash (S2)	23
Resin + Fiber + Fly-ash (S3)	22

O. Impact Test Properties

The mean value of impact energy of the glass fibers with varying percentages is 2.33 J for 100% resin and 9.67 J for 40% glass fiber and 60% resin and 20.667 J for 40% resin, 40% glass fiber and 20% fly ash. Though there may change in the values with increase in fiber percentage but it seems there is major difference with fly ash percentage. The test results shown in the table seems that different compositions has more impact energy in hybrid fiber composites.

The impact properties, which indicate a material's toughness, can be determined from the potential energy difference resulting from striking the material with a pendulum hammer. The impact properties include the notched impact strength, as determined with a V-shaped notch, and the un-notched impact strength. In determining the un-notched impact strength, the entire test piece receives the impact energy caused by the hammer striking, whereas in determining the notched impact strength, breakage is promoted by concentrating the impact energy on the notch.

V. CONCLUSION

The experimental investigation on the Evaluation of mechanical properties of artificial and hybrid fiber reinforced polymer composites were conducted. Properties such as the Tensile strength, Impact energy were evaluated from various experiments. The experiments lead us to the following conclusions obtained from this study:

- A. The successful fabrications of a new class of polymer based composites reinforced with artificial and natural fibers have been done.
- B. The maximum tensile strength among resin specimens is 12.842 Mpa whose composition is 100% resin.
- C. The maximum impact strength among resin specimens is 3 J whose composition is 100% resin.
- D. The maximum tensile strength among artificial fiber and resin reinforced composites is 56.421 Mpa whose composition is 40% artificial fiber and 60% resin.
- E. The maximum impact strength among artificial fiber and resin reinforced composites is 10 J whose composition is 40% fiber and 60% resin.
- F. The maximum tensile strength among hybrid fiber reinforced composites is 70.526 Mpa whose composition is 40% fiber, 40% resin and 20% fly ash.
- G. The maximum impact strength among hybrid fiber reinforced composites is 23 J whose composition is 40% fiber, 40% resin and 20% fly ash.

Possible use of these composites such as pipes carrying coal dust, industrial fans, helicopter fan blades, desert structures, low cost housing etc. is recommended. However, this study can be further extended in future to new types of composites using other inorganic materials/fillers and the resulting experimental findings can be similarly analysed.

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